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ABSTRACT

A study was conducted that attempted to show changes in electroencephalographic (EEG) patterns (identified using topographic EEG mapping) when children were required to perform the relatively simple task of button pressing during an eyes-open baseline session of low cognitive demand and a complex reaction time (RT) task of high cognitive demand. Subjects were four male and five female 10- to 12-year-old children. One of the boys was left-handed. Using past research, EEG patterns recorded two seconds prior to the button push for both conditions were analyzed into component frequencies using a Fast Fourier Transform algorithm. Results show a statistically significant decrease in beta activity during the performance of the more cognitively demanding task relative to the simple condition. Topographic and statistical probability maps suggested that this decrease occurred primarily in the frontal lobe of the left cerebral hemisphere and in the temporal and parietal lobes of the right hemisphere. Results are explained in terms of past EEG research, and possible psychophysiological applications to cognitive and educational research are discussed. Six figures illustrate the discussion. (Author/SLD)

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EEG PATTERNS RELATED TO COGNITIVE TASKS OF VARYING COMPLEXITY [1]

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Running Head: EEG PATTERNS

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ABSTRACT

The basic research literature needed for combining cognitive and psychophysiological approaches for use in educational research is quite thin. Consequently, a study was conducted which attempted to show changes in electroencephalographic (EEG) patterns (identified using Topographic EEG Mapping) when children were required to perform the relatively simple task of button pressing during an Eyes-open baseline session (low cognitive demand) and during a complex reaction time (RT) task (high cognitive demand). Based on past research, EEG recorded two seconds prior to the button push for both conditions were analyzed into component frequencies using a Fast Fourier Transform algorithm. Results showed that there was a statistically significant decrease in beta activity during the performance of the more cognitively complex RT task relative to the simple eyes-open, button push baseline condition. Topographic and statistical probability maps suggested that this decrease in beta activity for the RT task occurred primarily in the frontal lobe of the left cerebral hemisphere and in the temporal and parietal lobes of the right hemisphere. Results were explained in terms of past EEG research and possible psychophysiological applications to cognitive and educational research were given.

EEG PATTERNS RELATED TO COGNITIVE TASKS OF VARYING COMPLEXITY

With the recognition that neurons transmit electrical signals through biochemical means, there is growing interest in discovering relationships between the electrical activities of the human brain and thinking or cognitive processes in order to help solve the "brain/mind problem". Yet, much basic work needs to be done to discover the electrophysiological correlates of the various subcomponents or subroutines involved in complex information processing before research of this type can have direct application to education.

Reaction time is one of the prime indices used to measure the basic cognitive processes subserving complex learning by cognitive psychologists and psychophysiologists. However, reaction time measurements typically require the participant to push a button at the beginning and/or end of a cognitive performance. A major problem of using a motor act like a button press in psychophysiological or neurocognitive research is that electroencephalographic (EEG) measurements recorded just *prior* to the button push are related to both the cognitive process under study and the motor preparation for the subsequent button press. Therefore, before EEG and RT measurements can be successfully used together in cognitive and educational research, the contribution of button push preparation *per se* has to be compared

to preparation to push a button in an RT paradigm.

Thus, the purpose of this paper is to report the results of a study which attempted to show changes in electroencephalographic (EEG) patterns as children were required to perform the relatively simple task of button pressing during a baseline session to the more cognitively demanding complex RT task.

In our research, we utilize a relatively new technology called topographic EEG mapping of the brain's electrical (EEG) activity. This technology allows the cortical patterns of EEG activity to be graphically displayed from a subject engaged in tasks of varying cognitive complexity (Duffy, Burchfiel, & Lombroso, 1979; Torello, & Duffy, 1985). Figure 1 shows example maps.

Insert Figure 1 about here.

Since EEG can be collected during the performance of a task, it can be used as an on-line measure of cognitive processing (Dunn, 1985a). Thus, topographic imaging allows us to see patterns of EEG activity which could typically elude more traditional measures. In other words, differences in EEG patterns should be thought of as the major dependent variable in our research.

Four male and five female 10-12 year old children from a local elementary school volunteered as participants. One of the boys was left-handed.

The tasks the children were given were very simple. First, EEG was recorded when the children were asked to relax as much as possible with their eyes open while they stared at a blank computer screen. However, they were instructed to occasionally to push the a button that was used in the reaction time portion of the experiment that followed. In short, this condition controlled for the EEG activity generated by preparation for the button push, but it did not entail any EEG activity related to high-level cognitive processing. Two of these "button push" eyes open conditions were run. One was taken before the reaction-time task, while the other was taken after the reaction time task was given. Subjects averaged 10 button pushes for each baseline period, producing an average of 20 records for the control condition. No subject produced less than 7 usable records per baseline.

The other major condition was a simple reaction time task. Children were shown a list of 120 words flashed one at a time for 160 ms on a CRT. Some of the words (38) were followed by an asterisk. They were told that whenever a word with an asterisk appeared, they were to push the button as quickly as possible. Thus, as a result of our experimental manipulations, two

experimental conditions were produced. These conditions increased in cognitive load, from the simple eyes-open button push control condition (EBB) to the more complex reaction time (RT) task (the latter of which was more complex because it not only required a button push, but also included a discrimination between words with and without asterisks).

EEG data were recorded from 15 brain sites according to the international 10/20 system (Jasper, 1958), using a PDP 11/34a computer based brain imaging system developed and programmed by the second author. Eye movements and blinks were recorded from an electrode placed on the infraorbital ridge of the left eye which was referred to another electrode placed above the right eye on the supraorbital ridge. All active brain sites were referred to linked ears and Fpz served as subject ground. EEG data were collected based on two second epochs, sampled at 256 Hz. All EEG data were carefully edited off-line and any data containing artifacts (eye blinks, muscle movements, major saccades, etc.) were rejected.

Three months of careful examination of EEG data in our laboratory has shown that preparation for a button push occurs somewhere in a two second interval prior to the button push. Interestingly, this is the same interval used by Marlin Languis and his colleagues who are using a "back averaging" to study higher-level cognitive functioning reported last year at AERA (Schaff, Languis, & Russell, 1989). The resultant two second EEG

epochs from the two conditions (eyes-open baseline with button push, and reaction time) were subjected to a Fast Fourier Transform (FFT) using a Hamming window, and separate amplitude measurements for each frequency ranging from 1 to 36 Hz were calculated.

Results

Figures 1-6 contain the topographic images of the distribution of the various frequencies across the cerebral cortex of the brain that occurred during the performance of each of the conditions. The values of the scale to the right of all figures are in units of amplitude.

The exception is the scale for the statistical probability maps which show the areas of the cortex (e.g., Fz) which differed from condition "EBB" to condition "RT". The data that are mapped are actual "t" values (a "t" of 500 means the t = 5.00).

Figure 1 shows the frequency distribution from 11-22 Hz across the cortex that was related to the button-push control condition. Figure 2 shows the frequency distribution of the reaction time EEG from 11-22 Hz. It is clear from these figures that the EBB condition produced more mean amplitude in each of these frequencies than did the RT condition (especially in the 14-22 Hz range) than the RT condition. This is confirmed by Figure 3 which shows the statistical probability map (T map) comparing these two conditions. From this map it is clear that most of the significant differences between these two conditions

occurred primarily in the left-frontal cortex (14-22 Hz) and the right temporal and parietal areas (18-22 Hz).

Similar results occurred in the 23-34 Hz ranges. Figures 4 and 5 show the mean EEG amplitudes from the EEB and RT conditions, respectively. Figure 6 shows the statistical probability maps at those frequencies. Again there was a general pattern of left-frontal amplitude differences with the EEB condition producing greater mean amplitude than the RT condition at 26-34 Hz as well as more right-temporal activity from 23-34 Hz. There was also some right parietal amplitude differences at 24-28 and 31 Hz.

Insert Figures 2-6 about here

Through the utilization of topographic images and statistical probability maps, a clear pattern of amplitude differences emerged. It appears that when a cognitive load was added to a button push activity by adding a simple RT task, there was a general decrease in the beta frequency ranges of the EEG. More importantly, these changes occurred primarily in the frontal lobe of the left hemisphere and the temporal/parietal lobes of the right hemisphere.

Conclusions

Our results are contrary to traditional notions concerning EEG activity, namely that alpha is inversely related to mental processing, whereas beta is positively related to cognitive processing (e.g., Adrian & Matthews, 1935). This conventional wisdom, however, is currently being questioned (e.g., Dunn, 1985; Ray & Cole, 1985). Furthermore, in their classic study, Doyle, Ornstein and Galin (1974) obtained results that led them to state "If the beta activity (obtained) is bona fide, i.e., not related to alpha, then the pattern of activation is contrary to the commonly held view that cerebration increases beta; we find less beta over the hemisphere more primarily engaged." (p. 576). Thus, if the Doyle et. al, interpretation is correct, then our beta results suggest that reaction time engaged the left-frontal and right-temporal/parietal hemispheres more than did the mere motor preparation for button pushing. However, the role of alpha and beta activity in higher-order cognition is far from settled because so little research has been done. This makes research of the type presented here even more timely. Given the heterogeneity of our pilot study sample, the consistency of our preliminary results are highly promising.

In the continuation of our research, we hope to show relationships between EEG patterns of cognitive tasks like sentence processing and like reading extended discourse, thus, moving toward relationships between EEG patterns and real world

"school related" learning events. Besides the basic research interest, the marriage of real world learning to psychophysiological indices of that learning has great potential in the applied areas such as the diagnosis of different categories of children or adults labeled as having some type of learning or thought disorder.

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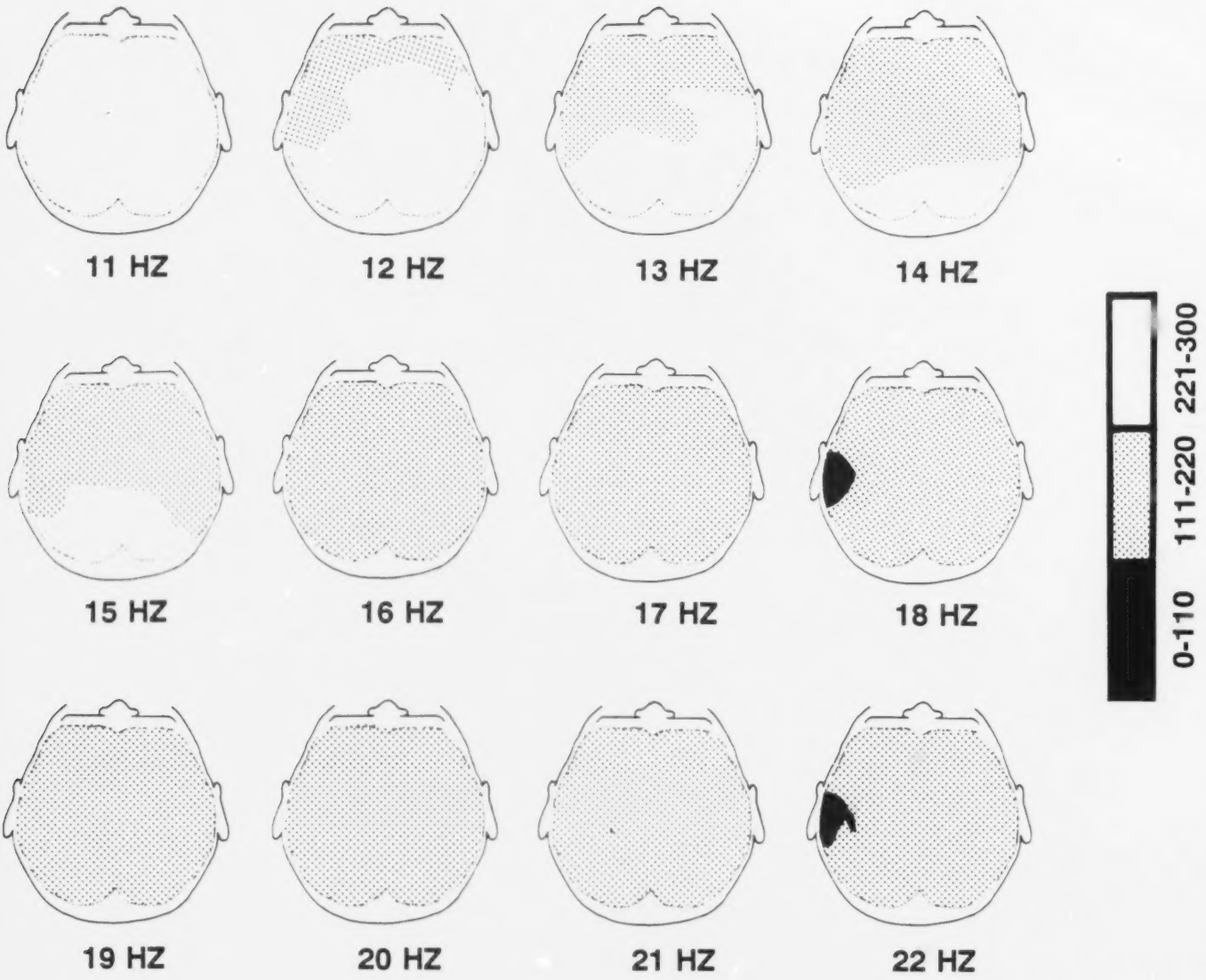

Figure 1. Topographic Maps from Eyes-Open, Button Push Baseline Condition (11-22 *Hz)*.

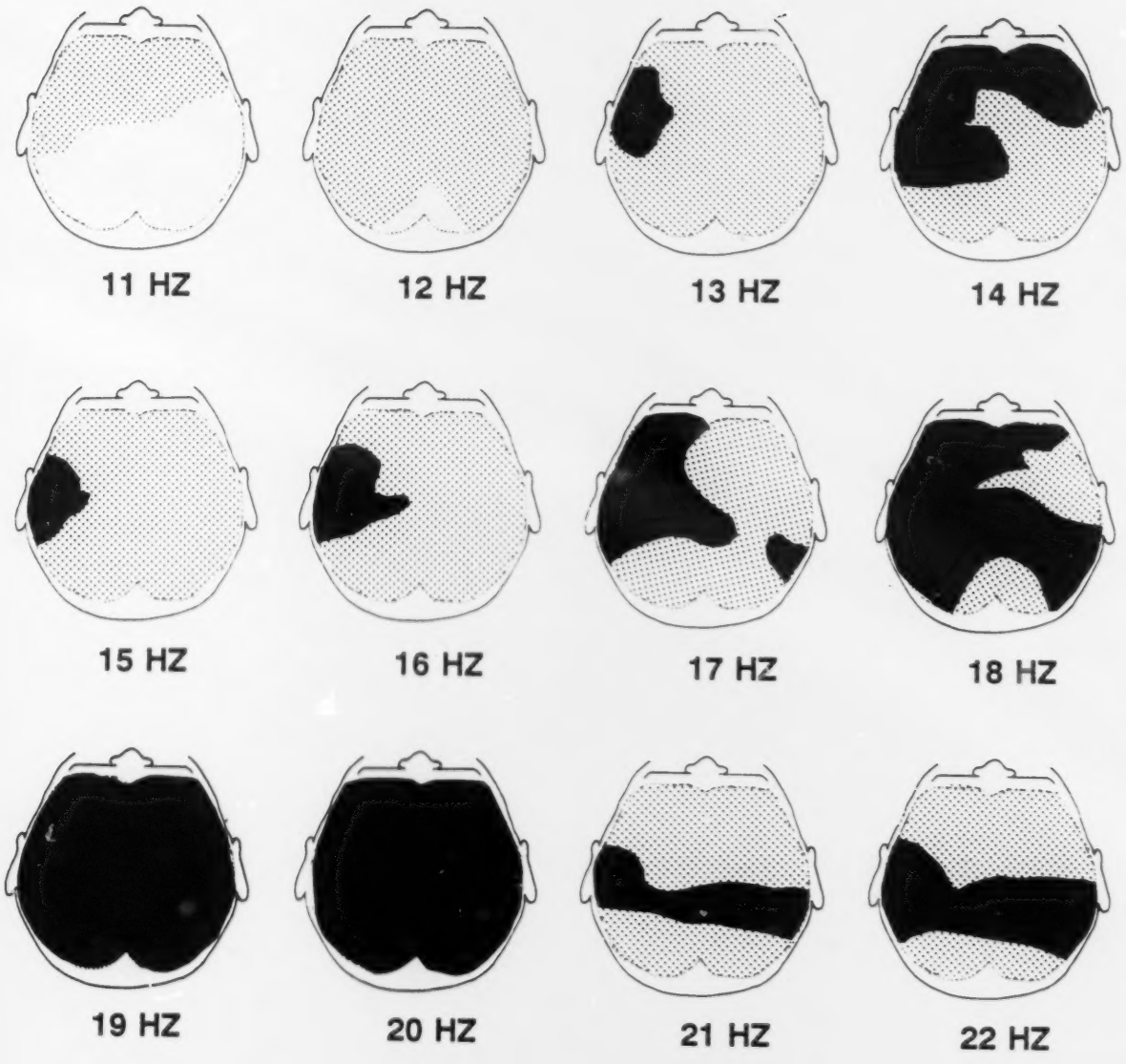

Figure 2. Topographic Maps from Reaction-Time Condition (11-22 *Hz*).

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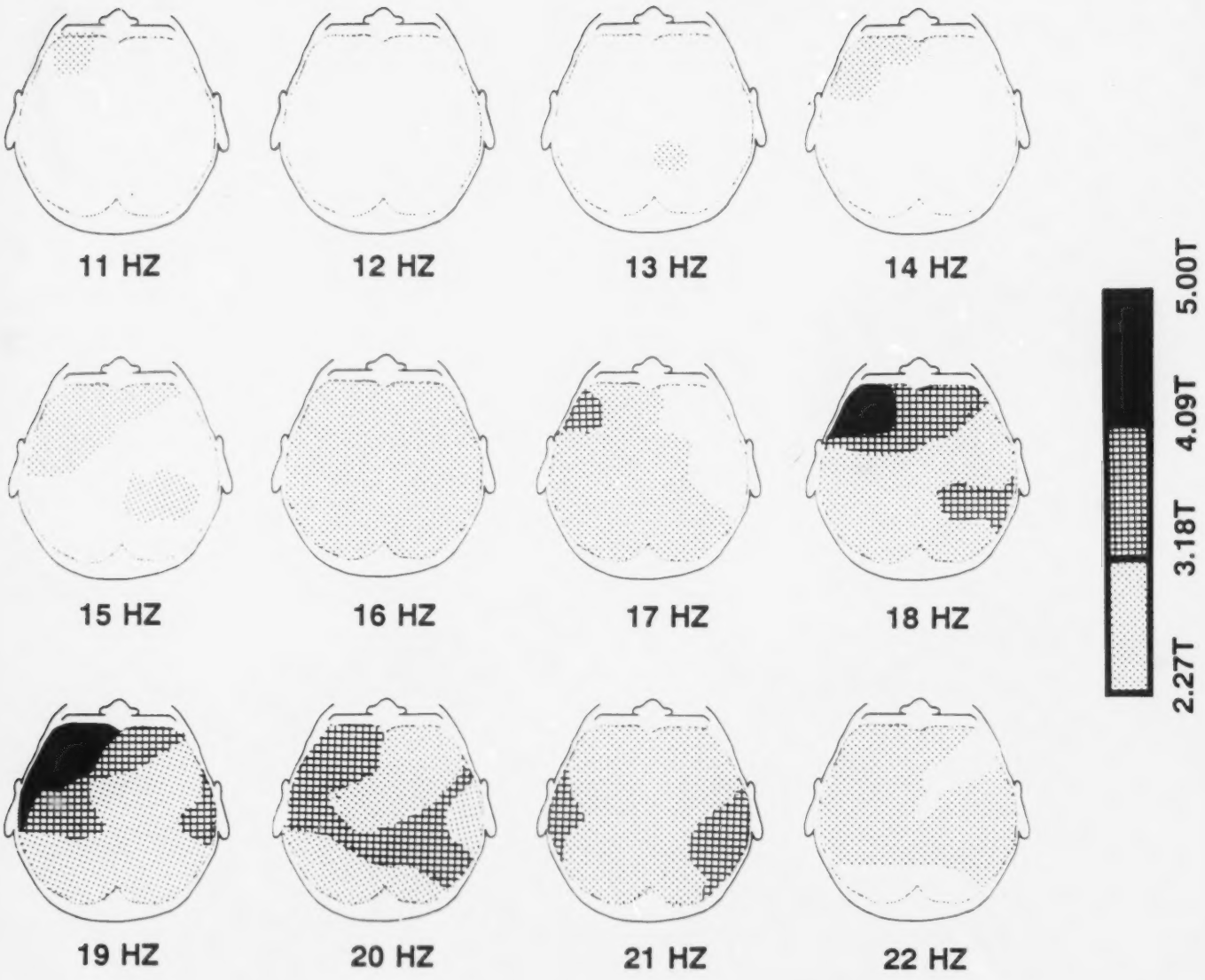

Figure 3. Statistical Probability Maps (T Maps) between EBB and RT Conditions (11-22 *Hz*).

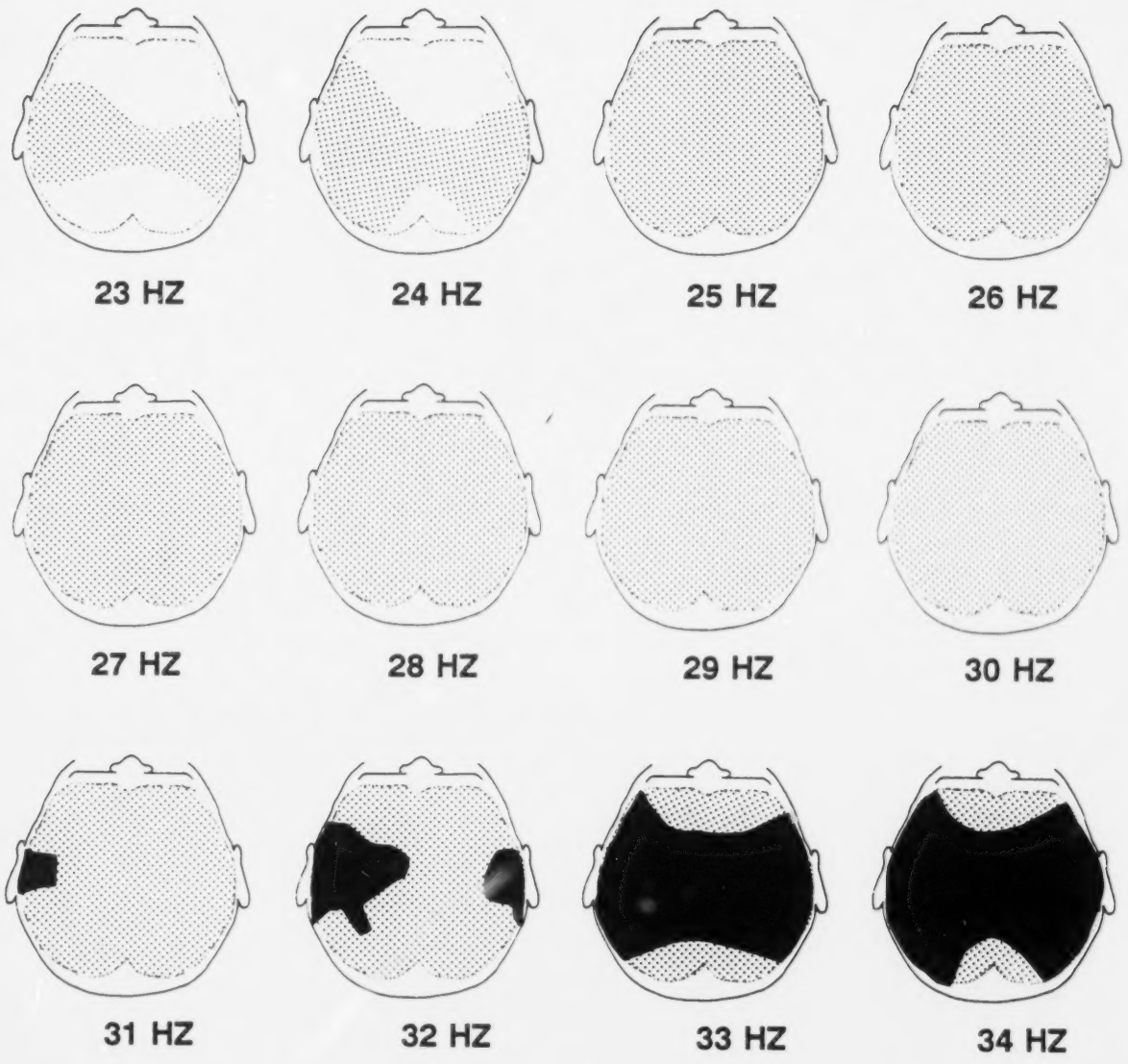

Figure 4. Topographic Maps from Eyes-Open, Button Push Baseline Condition (23-34 *Hz*).

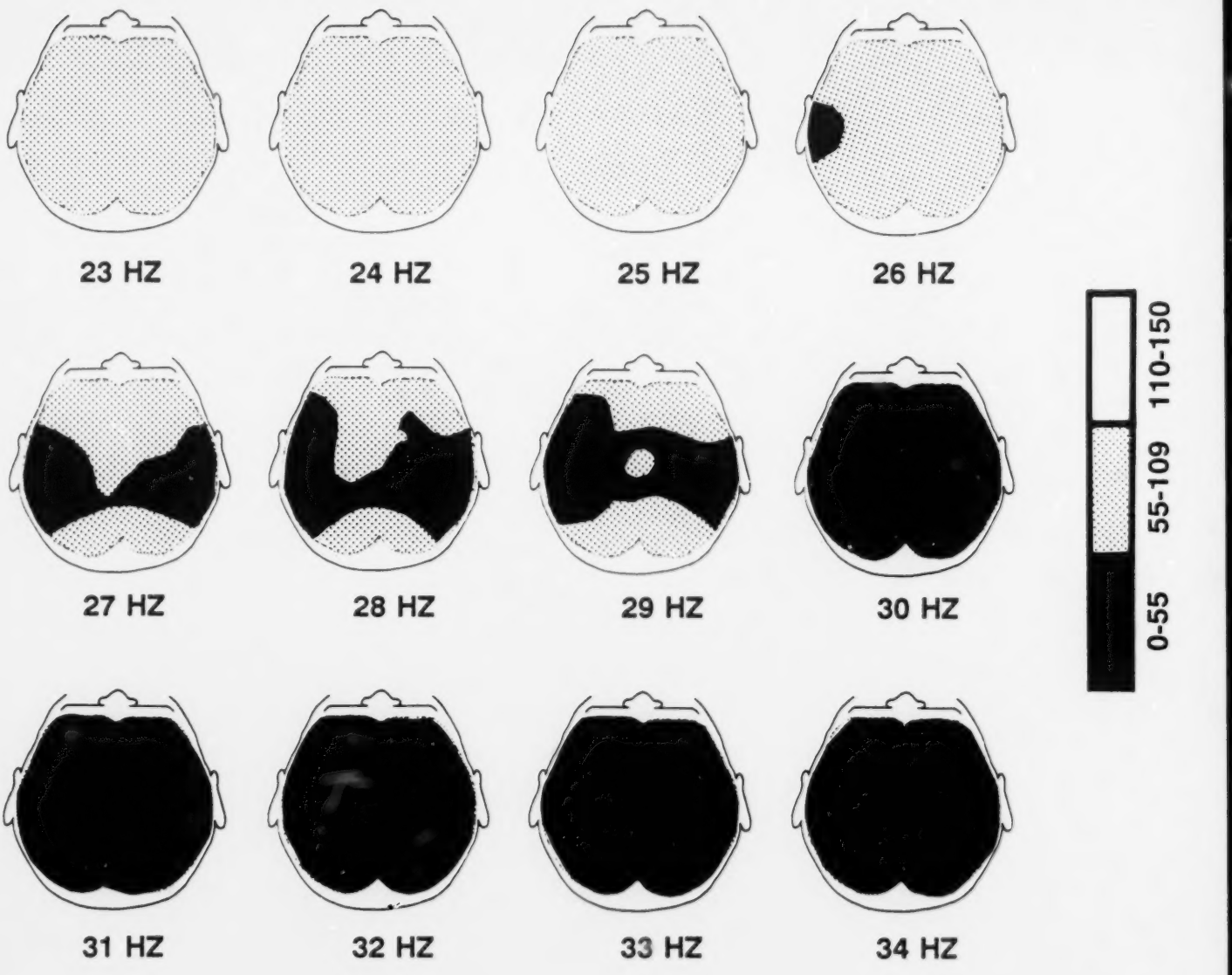

Figure 5. Topographic Maps from Reaction-Time Condition (23-34 *Hz*).

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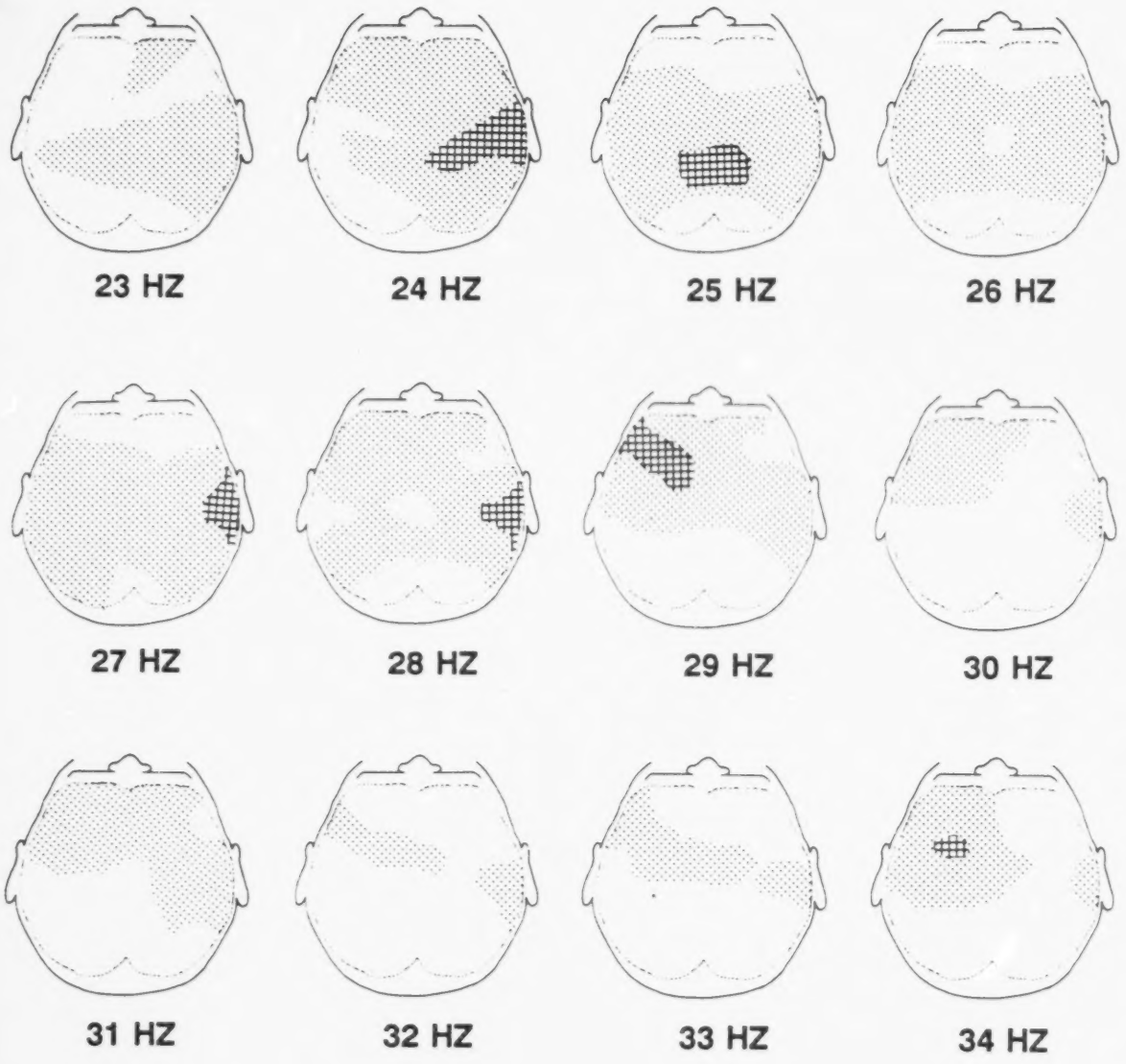

Figure 6. Statistical Probability Maps (T Maps) between EBB and RT Conditions (23-34 *Hz*).